Luncheon Remarks, Rodney E. Slater, Administrator, Federal Highway Administration

Earthquakes are a world-wide hazard. In the United States, the last two largest destructive earthquakes were the Loma Prieta earthquake in 1989 with 63 fatalities and $10 billion in damage and the Northridge earthquake in 1994 with 57 fatalities and $20 billion in damage. In Japan, the Kobe earthquake led to approximately 5,500 lives lost and more than $100 billion in damage.

Surface transportation is a vital component of the human lifeline. It links airports, train stations, harbors, manufacturing plants and residences. It is essential to the national economy to keep this transportation lifeline functioning during a natural hazard such as an earthquake. Bridges are the most vulnerable component of the surface transportation system to earthquake damage. Current bridge inventory in the United States is at approximately 575 thousand; about 60 percent of which were never designed with consideration for seismic forces.

In the United States the most significant knowledge with respect to the response of bridges to the forces imparted during a seismic event and the resulting damage to bridge structures has been gained in the last 25 years, that is, since the 1971 San Fernando earthquake.

Prior to the 1933 Long Beach earthquake, there were no special criteria for the seismic design of bridges in the United States. After the 1940 El Centro earthquake, minimal seismic design factors were developed for bridges.

With the 1971 San Fernando event, with a total of 62 bridges damaged, came the realization that the then current U.S. design specifications and practices contained a number of deficiencies. It was recognized that a considerable number of bridges could be expected to fail if subjected to moderate earthquakes. This earthquake provided the impetus to address the problem of retrofitting (strengthening) the existing bridge inventory to withstand the forces and displacements resulting from earthquakes.

Following the poor performance of bridges in the San Fernando earthquake, the FHWA and the California Department of Transportation (CALTRANS) began exhaustive studies into the seismic performance of bridges. This intense effort resulted in a series of publications, seismic design guidelines, and specifications for both new and existing bridges. In 1983 and 1987, FHWA published the "Seismic Retrofitting Guideline for Highway Bridges," and a "Seismic Design and Retrofit Manual for Highway Bridges." These guidelines and manuals were updated with current available knowledge, and published as the "Seismic Retrofitting Manual for Highway Bridges," in May 1995. FHWA's efforts in seismic retrofitting and design of highway bridges has the objective to advance a national understanding of earthquake resistant design, construction, and retrofit of highway bridges through the development and refinement of clear, concise, nationally applicable specifications and guides of recommended practice.

New technologies have evolved and have been implemented to retrofit bridges. Many of these are as a result of the lessons learned in the 1971 San Fernando, 1987 Whittier, 1989 Loma Prieta, and the 1994 Northridge earthquakes. The major causes of bridge failures that have occurred in these earthquakes have been: "pull off" and collapse of superstructures from too narrow support seats at abutments, piers and thermal expansion joints, resulting in loss of support of the superstructure; loss of bond between column reinforcing steel and footing concrete, causing pullout and column collapse; horizontal shear failure of supporting columns resulting from inadequate confinement reinforcing steel; and details that reduce the design elastic length of the column.

Research has been conducted to develop foundation soil response spectra so the seismic hazard and soil-structure interaction can be more accurately predicted. More stringent performance criteria have been adopted to prevent collapse or serious damage in major earthquakes. Soil liquefaction effects have been researched and appropriate mitigation techniques have been developed and are currently being implemented. The required confinement details have been developed to insure ductile performance in a seismic event, tested in half size laboratory models for performance, and then utilized in newer and retrofitted bridges.

Performance of highway bridges in the 1994 Northridge earthquake provided reasonable assurance that those bridges which were designed or retrofitted to new criteria and with improved structural details can withstand expected earthquakes without collapse or serious damage. Some damage is to be expected but repairs can be made, in most cases, without the disruption of traffic.

While we have learned something new from nearly every earthquake in California and other locations, the major causes of bridge damage and collapse have not changed since the San Fernando event; they are merely repeated again and again. And they will be repeated until the existing bridges are seismically retrofitted to current seismic safety standards.

Both the Kobe and Northridge earthquakes provided some significant shocks to the earthquake engineering community. The Kobe earthquake focused our attention to the Central and Eastern United States for two reasons:

1. Large damaging earthquakes can occur in the areas considered to have, on average, only moderate exposure to seismic hazards, such as from the New Madrid fault zone in Missouri, Kentucky, Illinois, Tennessee and Arkansas. The Japanese had previously identified the Kobe-Osaka region as an area of comparatively low seismic vulnerability and of low seismic intensity should an earthquake occur. Thus, bridges and buildings within that region were not designed to resist the same high standards as in Tokyo. Similarly, bridges in the Central and Eastern United States, until relatively recent, were not designed to provide any seismic resistance.

2. Many existing bridges in these areas have simple and/or continuous span superstructures supported by bearings on concrete columns and foundations which are designed and detailed lacking ductility and weak conventional bearings between superstructure and substructure.

Currently the FHWA has a number of activities underway toward developing and advancing earthquake engineering technologies to highway bridges:

- A 12 million dollar research program is underway at the National Center for Earthquake Engineering Research (NCEER) to study the seismic vulnerability of the existing Highway System. This study is developing better means of assessing the vulnerability of existing highways, bridges and tunnels; and of retrofitting structures, foundations and embankments. Besides superstructures, this contract is studying substructures, foundations, retaining structures, soils, tunnels, pavements and landslides. This project is in the fourth year of a six year plan.

- A 2.24 million dollar research program is also underway, at NCEER, to study the seismic vulnerability of new highway construction, and to develop seismic design standards and criteria for new bridges, tunnels and pavements. The development of analytical and design procedures for abutments and retaining walls is complete. New details to ensure ductility in columns and walls are being developed. This is a four year project and is in its third year.

- In recent years, many passive seismic isolation systems have been proposed by different manufacturers to the bridge industry in the United States. However, because of the proprietary nature of these systems and the lack of knowledge of their long term performance, there has been a reluctance on the part of the design community to use them. FHWA recognized the need to develop a testing and evaluation program for passive systems for both retrofit and new construction applications in bridges. A test plan was developed with the collaboration of FHWA, CALTRANS and the Highway Innovative Technology Evaluation Center (HITEC). Fourteen manufacturers are participating in this program.

The program will provided verifiable, credible information on the functional performance (seismic and non-seismic), practicality, durability, materials characterization, and dynamic behavior of various systems and components submitted for evaluation. The program is unique for its full scale dynamic testing of all the systems which is being conducted at the Energy Technology Engineering Center (ETEC) at Burbank, California.

- FHWA is cooperating with the University of California at San Diego to apply the new techniques of Fiber Composite Materials developed by the Department of Defense research for the seismic retrofitting of bridge columns. This column wrapping technology supplements other materials used to increase column ductility so that a bridge column can absorb more energy during a large earthquake.

- The FHWA has provided 500,000 dollars funding for post earthquake research. The performance of highway bridges during the Northridge earthquake has brought invaluable information to be considered in bridge design criteria. This project with CALTRANS and the University of California at Berkeley is investigating the seismic vulnerability of bridges using observations from the Northridge earthquake.

- A FHWA Seismic Design Training Course has recently been developed. The course covers state-of-the-practice procedure using seven examples to emphasize design methods and introduces the AASHTO seismic design specification for highway bridges. State engineers will improve their knowledge on analysis, dynamic modeling and detailing of highway bridges. A two day satellite seminar pilot course was held on April 25 and July 25, 1996. Approximately 600 engineers participated in this course at 20 locations.

- The FHWA has just announced a new feature of its new Seismic Design Training Project, the "Seismic Help Desk Service." This "Seismic Help Desk Service" is an innovative approach to training and is intended to provide three levels of service to State practicing bridge and geotechnical engineers. It allows a State the use of FHWA's contract with the consultant responsible for the development of the training course. The service is meant to provide easy and cost effective access to the consultant's seismic design experts in order to provide answers to seismic design questions, Level I Service; project specific seismic design assistance, Level II service; and the development/presentation of seismic training at the State's office that focuses on specific needs, Level III Service.

- FHWA and the Public works Research Institute (PWRI) of Japan are currently cooperating in a joint research study to clarify U.S. and Japanese design criteria for bridge piers. The task in this project was to design a single shaft highway bridge pier under both countries' seismic design codes, and construct scale models for a shaking table test at PWRI. The Japanese design included two different design cases: (1) the Japan Road Association design specification issued in 1990, and (2) a interim design specification for Road Bridge Design proposed in February, 1995. The U.S. design is based on the AASHTO design specification issued in 1995. Three 1/6 scale models of the prototype columns (2 Japanese and 1 U.S. specimen) were constructed and tested on a shake table at PWRI in July and August of 1996. The data from these tests are currently being evaluated.

In conclusion:

- Earthquakes are inevitable natural hazards, but need not be inevitable disasters. We can reduce losses of life, casualties and property from future earthquakes through prudent actions today.

- A system of Retrofitting Prioritization must be developed in those States where earthquakes can be expected. Seismic retrofitting is eligible for Federal bridge funding, however, due to limited funding and other high bridge needs, critical and important bridges in the system must be given priority for retrofit.

- There is a Need for Interaction Between Research and Practice. Research advances knowledge but must be conducted in concert with the testing of the theories by the design community in order to draw the applicable lessons for use in practice. This testing should also be used in reverse to assist the research community in looking at research that will support the needed advancements in practice.

- If we are to ever claim a victory over the devastating seismic forces of nature and progress in the battle against human insufficiency, we need commitment. We need a commitment to seismic research, implementation of the knowledge gained through research, and to training of people to effectively use that knowledge.